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**BELL & HOWELL, INC.**  
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

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**SUBJECT:** MSFN Navigation Support in Earth  
Parking Orbit - Case 310

**DATE:** September 23, 1968

**FROM:** R. M. Scott

## ABSTRACT

The tracking coverage for each of nineteen MSFN stations for the first four revolutions of a spacecraft in earth parking orbit was obtained for eleven launch azimuths from  $72^\circ$  to  $108^\circ$ . The points where translunar injection might occur (both Atlantic and Pacific opportunities) on each revolution were obtained for lunar days three through ten. The navigation data required for translunar injection was expressed in a set of constraints and the acceptable launch azimuth-lunar day combinations established for injection on the second and third revolutions of the parking orbit.

On the basis of the mission constraints stated in this memorandum, the MSFN will provide adequate navigation support for injection on the third revolution Pacific opportunity for all launch azimuths. The third revolution Atlantic opportunity receives adequate navigation support for all launch azimuths except  $72^\circ$  and  $108^\circ$ . Though not required by mission rules, a navigation update can be provided for many launch azimuth-lunar day combinations for injection at a second Pacific opportunity; very poor navigation support is provided for injection at a second Atlantic opportunity.

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BELLCOMM, INC.  
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MEMORANDUM FOR FILE

I. INTRODUCTION

The capability of the MSFN to provide navigation support to a spacecraft in a 100 nautical mile earth parking orbit (EPO) was studied. Interest centered upon the amount of and time when the tracking data becomes available. An assumed set of mission constraints are proposed and the tracking data available to support a navigation update is investigated. A method for presentation of this data is illustrated.

II. DISCUSSION

Nineteen MSFN stations, including both C-Band and USB equipped sites, were selected for this study.\* A 100 nautical mile circular orbit was assumed and the Tracking Analysis Program was employed to determine the elapsed time from Earth Parking Orbit Insertion (EPOI) to initial visibility of the spacecraft at each station and the time of the subsequent tracking arc. This data was determined for the initial four revolutions following EPOI for each of eleven launch azimuths ranging from  $72^\circ$  to  $108^\circ$  from Kennedy Spacecraft Center. Note that spacecraft visibility from the tracking site was assumed for all elevations above 5 degrees irrespective of azimuth from the tracking station. This data is listed in Appendix A in tabular form. Figures 1 through 11 are plots of this data for each launch azimuth.

In order to obtain a composite presentation of the tracking coverage obtained for all the launch azimuths studied, the tracking data was plotted in Figure 12 for C-Band data and Figure 13 for the USB data. Smooth curves were fitted to the end points of each stations data arc to indicate envelopes of tracking coverage across the range of launch azimuths. Where overlapping coverage from several stations occurs (as over the Eastern Test Range) a composite envelope was drawn to avoid

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\*The nineteen stations selected were those listed in "Support Requirements Reference Handbook for the Apollo Saturn IB/Saturn V Programs." (Revised July, 1966)

the need to code coverage of individual stations. These two figures provide a summary of the tracking data available from the MSFN for the first four earth-parking orbits for launch azimuths between 72° and 108°.

### III. ANALYSIS

Use of this data to estimate the MSFN navigation support capability can be illustrated by analysis of one phase of a Lunar mission; specifically, consider the earth parking orbit phase extending from Earth Parking Orbit Insertion (EPOI) to Translunar Injection (TLI). The objective is to establish the quantity and time history of the tracking data available from which a navigation update for the TLI maneuver may be calculated.

The initial step of this analysis was to relate the time TLI occurs to the tracking data. Based upon the approximation that translunar injection occurs on the parking orbit ground track 22 degrees down range from the pericynthion nadir, the times for insertion into parking orbit to TLI were determined (References 1 and 2). One Atlantic and one Pacific TLI opportunity exist in each revolution of the parking orbit. The two opportunities in the first revolution following launch are not considered; considering an eighty minute minimum SIVB engine restart time, all first Atlantic injection opportunities are lost as are all but certain final first Pacific opportunities. The TLI times for selected lunar days for the second and third Atlantic and the second and third Pacific opportunities (corresponding to injection on the second and third revolutions) are plotted in Figures 12 and 13. The third, fifth, seventh and tenth lunar days were plotted; approximate TLI times for intervening days can be interpolated from the figures. Lunar days are numbered starting from Southern Lunistis.

The amount of tracking data required and the time relationship of that data to the TLI maneuver are formulated into a set of constraints. In the present case these constraints are limited to the navigation function; mission requirements for voice, telemetry and command contacts are not considered except for the command contact needed to transfer a navigation update to the spacecraft prior to the TLI maneuver.

The constraints provide the following:

- a. Establishment of a time band referenced to the TLI maneuver when the navigation update will be transmitted to the spacecraft. The start of the time band must be near enough to the time of TLI to estab-

blish an upper limit on the build up of errors in the navigation update due to neglect of the effect of off-nominal venting when propagating the update forward to the time of TLI; the end of the time band must be sufficiently ahead of TLI to ensure transfer of the update to the CSM and launch vehicle IU prior to attitude maneuvers and other activities required prior to the TLI maneuver.

- b. Establishment of a time band from the end of the tracking contact to provide time to transmit the tracking data to MCC-H, to process the data in an edit and an orbit determination program, to verify the results and to relay the navigation update to the selected command station for transmission to the spacecraft.
- c. Establishment of a minimum amount of tracking data required for a navigation update and provide limits on when the data is recorded.

Following these guidelines a set of mission constraints for this analysis may be stated as follows:

- a. At least one four minute contact above 5° elevation with a ground station having command (and voice) capability is required during the one hour period beginning 90 minutes before and ending 30 minutes before translunar injection ignition.
- b. The final tracking contact used in processing a navigation update shall be completed at least 10 minutes prior to the start of the command contact required by the constraint in (a) above.
- c. A minimum of two tracking contacts of four minutes minimum duration above 5° elevation is required in the final orbit ending ten minutes prior to the start of the command contact specified in (a) above.

Based upon the tracking data and the time of TLI, a set of one command and two tracking stations satisfying the assumed mission constraints was selected for each of the launch azimuth - lunar day combinations. These results are presented in Tables I through IV for each of the four injection opportunities studied. Where a set of stations is not presented, one or more of the constraints is violated. In certain cases, however, where a four minute tracking arc is not available, a station providing a three minute track was substituted and

this fact noted. The C-Band tracking data from Pretoria was not considered when selecting tracking stations since this station may not be available to support a lunar mission; in addition, radar data from tracking ships was not considered. Further, the navigation update might be relayed through the tracking ship deployed to monitor the TLI maneuver to satisfy the first (command contact) constraint since the period of the nominal parking orbit is approximately eighty-eight minutes; use of the tracking ship for this function was not considered and a USB equipped site was generally available for this function. The sets of stations presented in these tables satisfy the constraints but may not be the stations employed to support a specific mission.

The decision to employ an Atlantic or a Pacific TLI will be made prior to launch of a lunar mission. Tables I and II summarize the capability of the MSFN to provide navigation support for an Atlantic injection under the assumed constraints. Of the eighty-eight launch azimuth-lunar day combinations displayed in Table I for injection at the second Atlantic opportunity only six combinations satisfy the constraints. An additional sixteen launch azimuth - lunar day combinations would be acceptable on the basis of a three minute instead of a four minute tracking arc requirement. As illustrated in Table II, the constraints are satisfied for injection at the third Atlantic opportunity for all launch azimuths from  $76^\circ$  through  $104^\circ$  for the lunar days studied. In this case, relaxation of the length of the tracking arc required from four to three minutes permits injection on lunar days seven through ten for a  $72^\circ$  launch azimuth and on lunar days five through ten for the  $108^\circ$  launch azimuth.

Injection on the second Pacific opportunity is supported with navigation data for all the lunar days studied for launch azimuths from  $90^\circ$  through  $104^\circ$  as illustrated in Table III. Reduction of the length of the required tracking arc from four to three minutes permits additional support for all the lunar days studied for launch azimuths of  $108^\circ$  and  $72^\circ$  through  $80^\circ$ . Injection on the second Pacific opportunity does not satisfy the constraints for launch azimuths of  $84^\circ$  and  $88^\circ$  except for the third lunar day.

As shown in Table IV, injection on the third Pacific opportunity is allowed for all launch azimuth - lunar day combinations.

The greater number of acceptable sets of launch azimuth - lunar day combinations available for translunar injection on the third opportunity as compared to the second opportunity for both Atlantic and Pacific injection permits greater mission flexibility. Consideration should be given to reducing the minimum length of tracking arc required to allow a greater number of launch azimuth - lunar day combinations to be employed. For the data generated for this study and presented in Appendix A, approximately 62% of the tracking contacts were four minutes or longer in duration, approximately 22% were at least three minutes but less than four, and the remaining 16% of the contacts were less than three minutes.

#### IV. CONCLUSIONS

Current mission plans do not require a navigation update prior to injection at a second opportunity though the existence of navigation data may be considered a plus factor for this case. However, a navigation update prior to injection on a third opportunity is required due to the effects of off-nominal venting. The data prepared for this study shows that for lunar days three through ten, the constraints specifying the availability of navigation data are satisfied for all launch azimuths for injection at a third Pacific opportunity. For injection at a third Atlantic opportunity, the navigation constraints are satisfied for all launch azimuths except  $72^\circ$  and  $108^\circ$ ; a reduction of the required length of the tracking arc from four to three minutes permits launch azimuths of  $72^\circ$  and  $108^\circ$  to be used for certain of the lunar days.

For injection on the second Pacific opportunity, the navigation data available does not satisfy the constraints for launch azimuths from  $72^\circ$  through  $88^\circ$  and launch azimuth  $108^\circ$  except for lunar day three which has acceptable launch azimuths from  $72^\circ$  through  $104^\circ$ . Relaxing the minimum length of tracking arc from four to three minutes salvages launch azimuths from  $72^\circ$  through  $80^\circ$  and the  $108^\circ$  launch azimuth.

Injection on the second Atlantic opportunity is very poorly supported by navigation data. Of the eighty-eight lunar day-launch azimuth combinations studied only six satisfy the navigation constraints. Sixteen additional combinations can be allowed if the required tracking arc is reduced from four to three minutes.

As noted above, for lunar days three through ten, navigation support satisfying the constraint is provided for all launch azimuths for TLI at the third Pacific opportunity and for all launch azimuths except 72° and 108° for TLI at the third Atlantic opportunity. As a matter of interest the navigation support for these cases for lunar days one and fourteen was investigated. Again satisfactory navigation support was provided for all launch azimuths for both these days for a Pacific injection and for all azimuths except 72° and 108° for an Atlantic injection.

A minimum set of mission constraints needs to be adopted to allow a determination to be made of the capability of the MSFN to provide adequate navigation support in earth parking orbit. In the establishment of these constraints the minimum amount of tracking data needed to yield adequate navigation accuracy should be determined to permit use of minimal length tracking arc's.

The presentation of tracking data for several orbits and numerous launch azimuths and indicating trans-lunar injection times for various lunar days in a form similar to Figures 12 and 13 appears to be most effective for mission planning purposes.

#### V. ACKNOWLEDGEMENT

The author is indebted to Miss M. V. Bullock for the generation of the tracking data used in this study.



R. M. Scott

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Attachments  
Appendix A

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APPENDIX A

1-21

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A-1

*EGL	Eglin	C
CNV	Cape Kennedy	C-S
GBI	Grand Bahama Is.	C
SSI	San Salvador I	C
*GTK	Grand Turk I	C
BDA	Bermuda	C-S
ANT	Antigua	C-S
CYI	Grand Canary I	C-S
ASC	Ascension	C-S
*PRE	Pretoria	C
CRO	Carnarvon	C-S
BRA	Canberra	S
GWM	Guam	S
HAW	Hawaii	C-S
CAL	Pt Arquello	C
ODS	Goldstone	S
GYM	Guaymas	S
WHS	White Sands	C
TEX	Corpus Christi	S

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\*May not be available

## Earth Parking Orbit Coverage - 72° Launch Azimuth

<u>Station</u>	<u>Times (minutes)</u>	Beginning of tracking, counted from EPØI Duration of tracking		
BDA	0 .2	88.3 4.8	181.5 4.3	
CYI	6.3 4.7	100.7 1.5		
CRØ	42.3 2.8	135.5 3.5	228 4.8	322.2 2
BRA	49.7 3.2			
GYM	78.2 4.7	171.3 4.5		264.7 4.2
WHS	79.7 4.2	172.3 4.7		265.3 4.7
TEX	81 4.7	174.5 4.2		267.7 4.5
EGL	83.5 4.7		176.7 4.7	269.7 4.7
CNV	85 4.3		178.2 4.5	271.2 4.7
GBI	85.8 3.7		179 4	271 4.7
SSI	87.5 2.2		180.3 3.3	272.8 4.7
HAW		161 2.8	253 4.7	347.5 2.2
CAL		169.7 4.2	262.3 4.7	
ØDS		170.5 4.2	263.2 4.5	
GTK			181.8 2.2	273.8 4.7

## Earth Parking Orbit Coverage - 72° Launch Azimuth (Cont.)

<u>Station</u>	<u>Times (minutes)</u>	Beginning of tracking, counted from EPØI		Duration of tracking
ASC		198.7	290.2	
		1.7	4.5	
PRE		208.7	301.8	
		4.5	4.3	
ANT			276.3	
			4.8	
GWM			333.5	
			3.5	

## Earth Parking Orbit Coverage - 76° Launch Azimuth

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI Duration of pass		
EGL	83.5 4.8	176.7 4.7	270 4	
CNV	85 4.5	178.2 4.7	271.5 4	
GBI	85.7 4.2	178.7 4.7	272 4.2	
SSI	87 3.3	179.8 4.5	273 4.3	
GTK	89 1	181.2 3.8	273.8 4.7	
BDA	88.5 4.5	182 3.3		
ANT		183.8 3.5	276.5 4.5	
CYI	6.5 4.3			
ASC		197.5 3.8	290.7 3.7	
PRE		208.7 4.5	301.8 4.3	
CRØ	42.2 3.5	135.2 4.3	228.2 4.5	
BRA	no tracking			
GWM			333 4.3	
HAW		160.5 3.7	253 4.7	347.5 2.5
CAL		169.7 4	262.3 4.5	

## Earth Parking Orbit Coverage - 76° Launch Azimuth (Cont.)

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI		Duration of pass
ØDS		170.5	263.3	
		4	4.2	
GYM	78.2	171.3	264.5	
	4.7	4.5	4.7	
WHS	79.7	172		265.3
	4.2	4.7		4.7
TEX	81	174.5		267.5
	4.7	4.3		4.8

## Earth Parking Orbit Coverage - 80° Launch Azimuth

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI Duration of pass		
EGL	83.5 4.8	176.7 4.7	270.7 2.5	
CNV	85 4.7	178.2 4.7	272.3 2.2	
GBI	85.5 4.7	178.7 4.8	272.7 2.8	
SSI	86.8 4	179.8 4.7	273.5 3.3	
GTK		88.2 3	180.8 4.5	274.3 3.7
BDA		88.7 4.2		
ANT			183.3 4.5	277 3.5
CYI	7 3.2			
ASC			197.2 4.5	291.5 2.2
PRE		116.8 2.2	208.5 4.8	301.8 4.5
CRØ	42 4.2	135 4.7	228.7 3.5	
BRA	no tracking			
GWM				332.7 4.8
HAW		160 4.5	253.2 4.3	347.3 3
CAL		169.7 3.8	262.5 4	

## Earth Parking Orbit Coverage - 80° Launch Azimuth (Contd.)

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI		Duration of pass
ØDS	79.2 .8	170.7 3.7	263.5	3.5
GYM	78.2 4.7	171.3 4.7	264.5	4.8
WHS	79.5 4.3	172.3 4.7		265.7 4
TEX	81.2 4.7	174.3 4.7		267.5 4.7

## Earth Parking Orbit Coverage - 84° Launch Azimuth

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI Duration of pass		
EGL	83.5 4.7	176.8 4.2		
CNV	85 4.7	178.3 4.2		
GBI	85.5 4.7	178.8 4.5		
SSI	86.7 4.5	179.8 4.7		
GTK	87.8 4	180.7 4.8	276 .3	
BDA		88.8 3.5		
ANT		90.8 3	183.3 4.7	
CYI	no tracking			
ASC		197 4.8		
PRE		116 3.7	208.5 4.8	302 4.5
CRØ	41.8 4.5	135 4.7		
BRA	no tracking			
GWM			240.8 2.3	332.8 4.7
HAW		159.8 4.7	253.3 4.2	347.3 3.3
CAL	77.7 2	169.7 3.7	262.8 3.2	
ØDS	78.5 2	170.7 3.3	263.8 2.5	

## Earth Parking Orbit Coverage - 84° Launch Azimuth (Cont.)

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI		Duration of pass
GYM	78 4.8	171.3 4.7	264.5 4.7	
WHS	79.5 4.2	172.5 4.3		266 3
TEX	81.2 4.7	174.3 4.8		267.8 4

## Earth Parking Orbit Coverage - 88° Launch Azimuth

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI Duration of pass		
EGL	83.5 4.7	177.2 3.3		
CNV	85 4.7	178.7 3.3		
GBI	85.5 4.8	179.2 3.7		
SSI	86.5 4.8	180 4.2		
GTK	87.7 4.5	180.8 4.5		
BDA		89.5 2		
ANT		90.3 4.2	183.3 4.5	
CYI	no tracking			
ASC		104.5 3.5	197.3 4.2	
PRE		115.7 4.2	208.5 4.8	302 4.5
CRØ	41.8 4.7	135.2 4.2		
BRA	no tracking			
GWM			239.8 4.2	333.2 4
HAW	67.7 2.8	159.8 4.7	253.7 3.8	347.3 3.5
CAL	77.2 2.8	169.7 3.5	263.2 2.3	
ØDS	78 2.7	170.7 3.2		

Earth Parking Orbit Coverage - 88° Launch Azimuth (Contd.)

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI	Duration of pass
GYM	78 4.8	171.3 4.8	264.7 4.3
WHS	79.3 4.3	172.5 4	267 .8
TEX	81.2 4.7	174.3 4.7	268.3 2.8

## Earth Parking Orbit Coverage - 90° Launch Azimuth

<u>Stations</u>	<u>Times (minutes)</u>	Beginning of tracking counted from EPØI Duration of Tracking		
CRØ	41.7 4.8	135.3 3.8		
HAW	67.2 3.8	159.8 4.7	253.8 3.7	347.3 3.7
CAL	77 3	169.7 3.5	263.5 1.5	
ØDS	77.8 2.8	170.7 3		
GYM	78 4.8	171.3 4.7	264.8 4	
WHS	79.3 4.3	172.5 3.8		
TEX	81.2 4.7	174.3 4.7		269 1.3
EGL	83.5 4.5		177.5 2.5	
CNV	85 4.7		179 2.5	
GBI	85.5 4.8		179.3 3.2	
SSI	86.5 4.8		180.2 3.7	
GTK	87.7 4.5		181 4	
ANT		90.2 4.5	183.7 3.8	
ASC		104.2 4.2	197.7 3.5	
PRE		115.5 4.5	208.7 4.5	302 4.5
GWM			239.7 4.5	333.3 3.7

## Earth Parking Orbit Coverage - 92° Launch Azimuth

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI Duration of pass		
EGL	83.7 4.3	178	1.5	
CNV	85 4.5	179.7	1	
GBI	85.5 4.7	179.8	2.2	
SSI	86.5 4.8	180.5	2.8	
GTK	87.5 4.7	181.3	3.3	
BDA	no tracking			
ANT		90.2	183.8	
		4.5	3.3	
CYI	no tracking			
ASC		103.8	198.2	
		4.7	2.5	
PRE	24 1.5	115.3	208.7	302
		4.7	4.5	4.7
CRØ	41.7 4.8	135.7		
		3		
BRA	no tracking			
GWM			239.5	333.8
			4.8	2.7
HAW	67 4.2	160	253.8	347.3
		4.5	3.7	3.8
CAL	76.7 3.5	169.5		
		3.5		
ØDS	77.7 3.2	170.7		
		2.8		

## Earth Parking Orbit Coverage - 92° Launch Azimuth (Cont.)

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI Duration of pass
GYM	78.2 4.7	171.3 4.7
WHS	79.3 4.3	172.7 3.7
TEX	81.2 4.7	174.5 4.3

## Earth Parking Orbit Coverage - 96° Launch Azimuth

<u>Station</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI	Duration of pass	
EGL	83.7 4.2			
CNV	85 4.3			
GBI	85.5 4.5			
SSI	86.5 4.7			
GTK	87.5 4.8	182.8 .2		
BDA	no tracking			
ANT	0 .5	90 4.8		
CYI	no tracking			
ASC		103.8 4.7		
PRE	22.8 3.7	115.3 4.7	208.7 4.5	302 4.7
CRØ	41.8 4.7			
BRA	no tracking			
GWM		147.5 2.5	239.5 4.7	
HAW	66.7 4.7	160.2 4.2	254.2 3.2	347.3 4
CAL	76.3 3.8	169.5 3.3		
ODS	77.3 3.5	170.7 2.7		

## Earth Parking Orbit Coverage - 96° Launch Azimuth (Cont.)

<u>Station</u>	<u>(minutes)</u>	Beginning of pass, counted from EPØI Duration of pass
GYM	78.2 4.7	171.3 4.7
WHS	79.2 4.3	172.7 3.2
TEX	81.2 4.7	174.5 4.2

## Earth Parking Orbit Coverage - 100° Launch Azimuth

<u>Stations</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI Duration of pass		
EGL	83.7 3.8			
CNV	85.2 3.8			
GBI	85.7 4.2			
SSI	86.7 4.3			
GTK	87.5 4.7			
BDA	no tracking			
ANT	0 1	90.2		
CYI	no tracking			
ASC	11.3 3.5	104.2 4		
PRE	22.3 4.5	115.5 4.5	208.8 4.3	302 4.7
CRØ	41.8 4.5			
BRA	no tracking			
GWM		146.7 4.2	240 3.7	
HAW	66.7 4.7	160.7 3.3	254.7 2.5	347.3 4.2
CAL	76.2 4.2	169.3 3.3		
ØDS	77 4	170.7 2.3		

## Earth Parking Orbit Coverage - 100° Launch Azimuth (cont.)

<u>Stations</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI Duration of pass
GYM	78.2 4.7	171.3 4.5
WHS	79.2 4.3	173 2.3
TEX	81.2 4.7	174.8 3.3

## Earth Parking Orbit Coverage - 104° Launch Azimuth

<u>Stations</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI	Duration of pass	
EGL	83.7 3.7			
CNV	85.3 3.3			
GBI	85.8 3.7			
SSI	86.8 3.8			
GTK	87.7 4.2			
BDA	no tracking			
ANT	0 1.3	90.3 4		
CYI	no tracking			
ASC	10.7 4.7	105.3 1.5		
PRE	22.2 4.7	115.7 4	209.2 4	302 4.7
CRØ	42 4			
BRA	no tracking			
GWM		146.3 4.8	241.7 .3	
HAW	67 4	161.8 1.3	255 2	347.2 4.5
CAL	76 4.3	169.3 3.2		
ODS	76.8 4.2	170.7 2		

Earth Parking Orbit Coverage - 104° Launch Azimuth (Contd.)

<u>Stations</u>	<u>Times (minutes)</u>	Beginning of pass, counted from EPØI Duration of pass
GYM	78.2 4.7	171.3 4.5
WHS	79 4.5	173.3 1.3
TEX	81.2 4.7	175.2 2.3

## Earth Parking Orbit Coverage - 108° Launch Azimuth

<u>Stations</u>	<u>Times (minutes)</u>	Beginning of tracking counted from EPØI Duration of tracking		
ANT	0 1.5	90.8		
ASC	10.7 4.7			
PRE	22.3 4.3	116.3 3	209.3 3.7	302 4.7
CRØ	42.2 3.5			
GWM	54.8 2	146.5 4.3		
HAW	67.8 2.3		255.7 1	347.2 4.5
CAL	75.8 4.5	169.2 3.2		
ØDS	76.7 4.3	170.7 1.7		
GYM	78.3 4.5	171.3 4.2		
WHS	78.8 4.7			
TEX	81.2 4.7			
EGL	83.8 3			
CNV	85.5 2.5			
GBI	86 3			
SSI	87 3.2			
GTK	87.8 3.5			

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## SECOND ATLANTIC OPPORTUNITY

LUNAR DAYS

	3	4	5	6	7	8	9	10
LAUNCH AZIMUTH - DEGREES								
108								
104						HAW-C CRO-T ASC-T	HAW-C CRO-T ASC-T	HAW-C CRO-T ASC-T
100						HAW-C CRO-T ASC-T*	HAW-C CRO-T ASC-T*	ODS-C HAW-T CRO-T
96								
92							GYM-C HAW-T CRO-T	GYM-C HAW-T CRO-T
90							GYM-C HAW-T* CRO-T	GYM-C HAW-T* CRO-T
88								
84								
80						GYM-C CRO-T CYI-T*	GYM-C CRO-T CYI-T*	GYM-C CRO-T CYI-T*
76						GYM-C CRO-T* CYI-T	GYM-C CRO-T* CYI-T	GYM-C CRO-T* CYI-T
72					GYM-C BRA-T* CYI-T	GYM-C BRA-T* CYI-T	GYM-C BRA-T* CYI-T	GYM-C BRA-T* CYI-T

NOTE: \*DENOTES TRACKING PASSES GREATER THAN 3 MINUTES IN LENGTH BUT LESS THAN 4 MINUTES.

TABLE I  
COMMAND AND TRACKING STATIONS SATISFYING  
MISSION CONSTRAINTS FOR TRANSLUNAR  
INJECTION ON SECOND ATLANTIC OPPORTUNITY

THIRD ATLANTIC OPPORTUNITY  
LUNAR DAY

	3	4	5	6	7	8	9	10
108			GWM-C USA-T CRO-T*	GWM-C USA-T CRO-T*	GWM-C USA-T CRO-T*	GWM-C USA-T CRO-T*	GWM-C USA-T CRO-T*	GWM-C USA-T CRO-T*
104	ANT-C HAW-T CRO-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T
100	ASC-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T	GWM-C USA-T HAW-T
96	ASC-C USA-T HAW-T	ASC-C USA-T HAW-T	ASC-C USA-T HAW-T	ASC-C USA-T HAW-T	HAW-C ASC-T USA-T	HAW-C ASC-T USA-T	HAW-C ASC-T USA-T	GYM-C HAW-T ASC-T
92	ASC-C USA-T HAW-T	ASC-C USA-T HAW-T	ASC-C USA-T HAW-T	HAW-C ASC-T ANT-T	HAW-C ASC-T ANT-T	HAW-C ASC-T ANT-T	GYM-C HAW-T ASC-T	GYM-C HAW-T ASC-T
90	ASC-C GYM-T CRO-T	ASC-C GYM-T CRO-T	ASC-C GYM-T CRO-T	ASC-C GYM-T CRO-T	HAW-C ASC-T ANT-T	HAW-C ASC-T ANT-T	HAW-C ASC-T ANT-T	GYM-C HAW-T ASC-T
88	CRO-C USA-T	CRO-C USA-T	CRO-C USA-T	CRO-C USA-T	HAW-C CRO-T USA-T	HAW-C CRO-T USA-T	HAW-C CRO-T USA-T	GYM-C HAW-T CRO-T
84	CRO-C USA-T	CRO-C USA-T	CRO-C USA-T	HAW-C CRO-T USA-T	HAW-C CRO-T USA-T	HAW-C CRO-T USA-T	GYM-C HAW-T CRO-T	GYM-C HAW-T CRO-T
80	CRO-C USA-T	CRO-C USA-T	HAW-C CRO-T BDA-T	HAW-C CRO-T BDA-T	HAW-C CRO-T BDA-T	HAW-C CRO-T BDA-T	GYM-C HAW-T CRO-T	GYM-C HAW-T CRO-T
76	CRO-C USA-T	CRO-C USA-T	CRO-C USA-T	CRO-C USA-T	CRO-C USA-T	ODS-C CRO-T BDA-T	ODS-C CRO-T BDA-T	ODS-C CRO-T BDA-T
72					ODS-C CRO-T* BDA-T	ODS-C CRO-T* BDA-T	ODS-C CRO-T* BDA-T	ODS-C CRO-T* BDA-T

NOTES: USA REFERS TO THOSE STATIONS PROVIDING TRACKING AND  
COMMUNICATIONS OVER AND CONTIGUOUS TO CONTINENTAL  
UNITED STATES: CAPE KENNEDY; BERMUDA; ANTIGUA; GRAND  
CANARY ISLAND; ASCENSION; GOLDSTONE; GUAYMAS; CORPUS  
CHRISTI.

\* DENOTES TRACKING PASSES GREATER THAN 3 MINUTES IN LENGTH  
BUT LESS THAN 4 MINUTES.

TABLEII

COMMAND AND TRACKING STATIONS SATISFYING  
MISSION CONSTRAINTS FOR TRANSLUNAR  
INJECTION ON THIRD ATLANTIC OPPORTUNITY

## SECOND PACIFIC OPPORTUNITY

LUNAR DAYS

	3	4	5	6	7	8	9	10
108	TEX-C CRO-T* ASC-T	TEX-C CRO-T* ASC-T	TEX-C CRO-T* ASC-T	TEX-C CRO-T* ASC-T	TEX-C CRO-T* ASC-T	TEX-C CRO-T* ASC-T	TEX-C CRO-T* ASC-T	TEX-C CRO-T* ASC-T
104	ANT-C HAW-T CRO-T	ANT-C HAW-T CRO-T	ANT-C HAW-T CRO-T	ANT-C HAW-T CRO-T	ANT-C HAW-T CRO-T	ANT-C HAW-T CRO-T	ANT-C HAW-T CRO-T	ANT-C HAW-T CRO-T
100	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T
96	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T
92	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T
90	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T	ASC-C USA-T
88	CRO-C USA-T							
84	CRO-C USA-T							
80	CRO-C USA-T	BDA-C CRO-T CYI-T*	BDA-C CRO-T CYI-T*	BDA-C CRO-T CYI-T*	BDA-C CRO-T CYI-T*	BDA-C CRO-T CYI-T*	BDA-C CRO-T CYI-T*	BDA-C CRO-T CYI-T*
76	CRO-C USA-T	BDA-C CRO-T* CYI-T	BDA-C CRO-T* CYI-T	BDA-C CRO-T* CYI-T	BDA-C CRO-T* CYI-T	BDA-C CRO-T* CYI-T	BDA-C CRO-T* CYI-T	BDA-C CRO-T* CYI-T
72	BDA-C GYM-T BRA-T* CYI-T	BDA-C GYM-T BRA-T* CYI-T	BDA-C GYM-T BRA-T* CYI-T	BDA-C GYM-T GRA-T* CYI-T	BDA-C GYM-T BRA-T* CYI-T	BDA-C BRA-T* CYI-T	BDA-C BRA-T* CYI-T	BDA-C BRA-T* CYI-T

NOTES: USA REFERS TO THOSE STATIONS PROVIDING TRACKING AND COMMUNICATIONS OVER AND CONTIGUOUS TO CONTINENTAL UNITED STATES: CAPE KENNEDY; BERMUDA; ANTIGUA; GRAND CANARY ISLAND; ASCENSION; GOLDSTONE; GUAYMAS; CORPUS CHRISTI.

\* DENOTES TRACKING PASSES GREATER THAN 3 MINUTES IN LENGTH BUT LESS THAN 4 MINUTES.

TABLE III

COMMAND AND TRACKING STATIONS SATISFYING  
MISSION CONSTRAINTS FOR TRANSLUNAR  
INJECTION ON SECOND PACIFIC OPPORTUNITY

## THIRD PACIFIC OPPORTUNITY

## LUNAR DAY

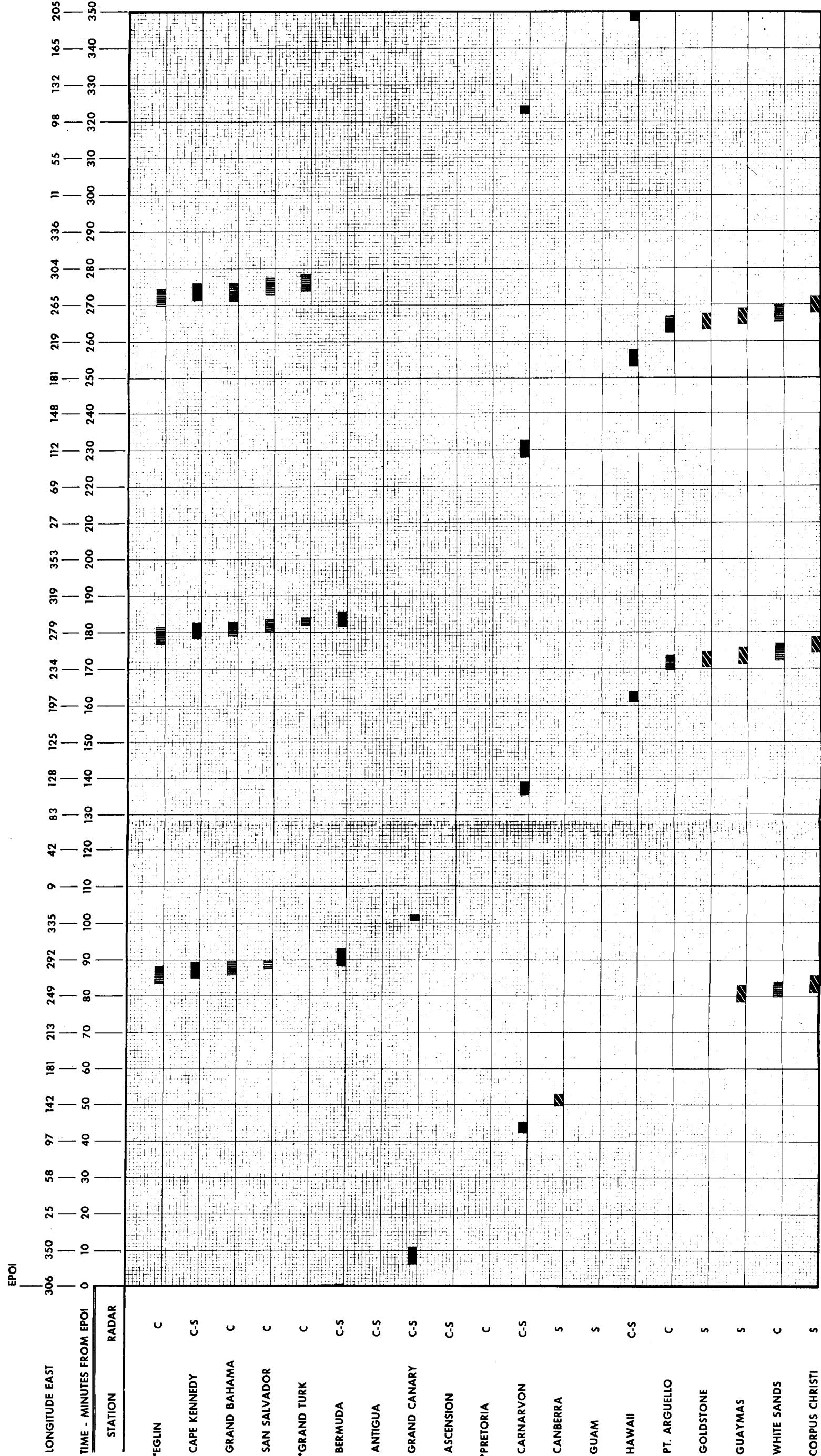
	3	4	5	6	7	8	9	10
108	GYM-C GWM-T TEX-T							
104	GYM-C GWM-T ANT-T							
100	GYM-C GWM-T ASC-T							
96	TEX-C HAW-T ASC-T							
92	TEX-C HAW-T ASC-T							
90	TEX-C HAW-T ASC-T							
88	ASC-C GYM-T HAW-T							
84	ASC-C CNV-T GYM-T							
80	ASC-C CNV-T GYM-T							
76	CRO-C CNV-T ODS-T	CNV-C CRO-T BDA-T						
72	CRO-C BDA-T ODS-T	BDA-C CRO-T BDA-T						

LAUNCH AZIMUTH - DEGREES

TABLE IV

COMMAND AND TRACKING STATIONS SATISFYING  
 MISSION CONSTRAINTS FOR TRANSLUNAR  
 INJECTION ON THIRD PACIFIC OPPORTUNITY

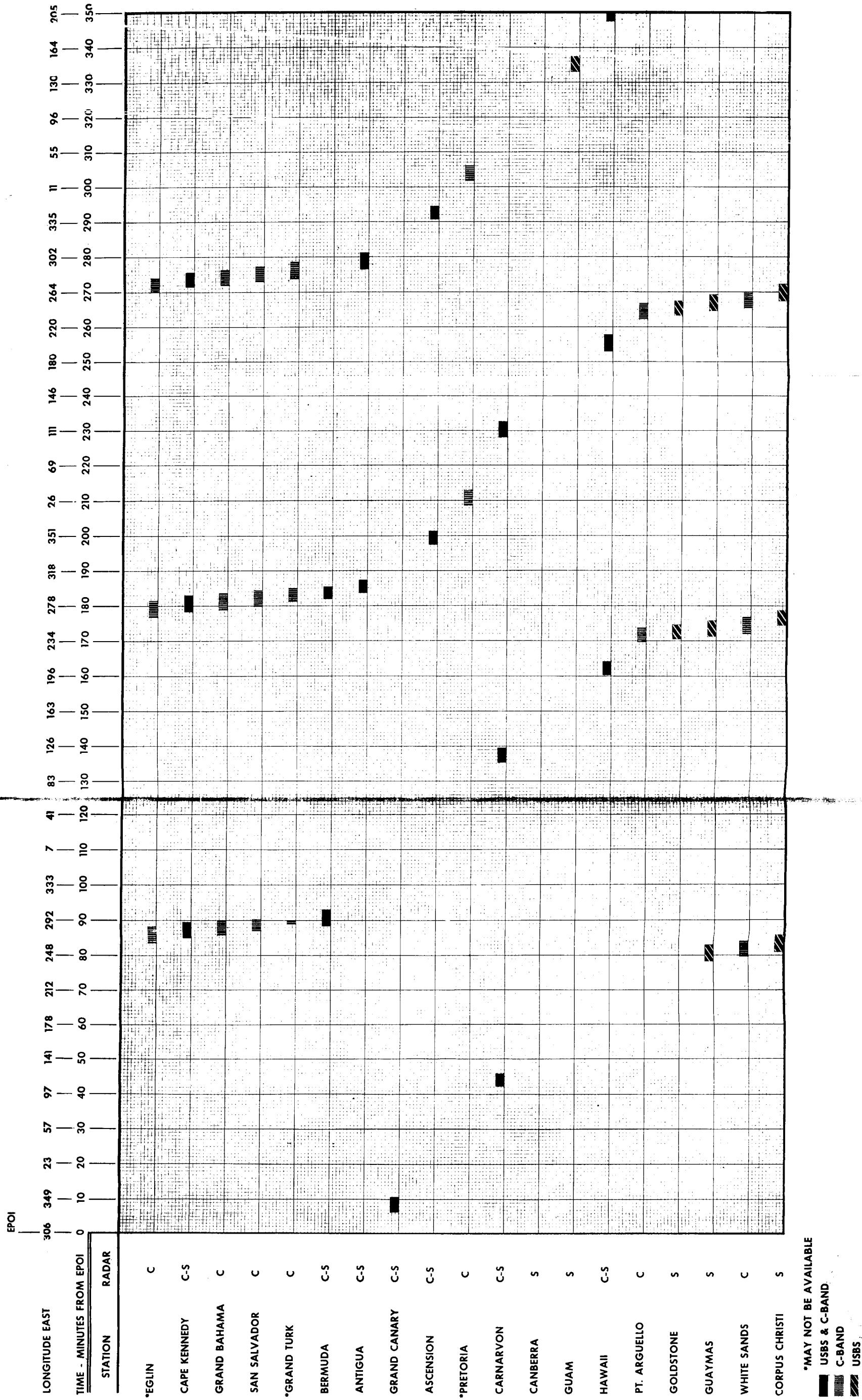
**FIGURE 1**  
**RADAR TRACKING COVERAGE 100 NM ORBIT 72° LAUNCH AZIMUTH**  
**INITIAL FOUR ORBITS**



\*MAY NOT BE AVAILABLE  
 USBS & C-BAND  
 C-BAND  
 USBS

## FIGURE 2

**RADAR TRACKING COVERAGE 100 NM ORBIT 76° LAUNCH AZIMUTH  
INITIAL FOUR ORBITS**



**FIGURE 3**  
**RADAR TRACKING COVERAGE 100 NM ORBIT 80° LAUNCH AZIMUTH**  
**INITIAL FOUR ORBITS**

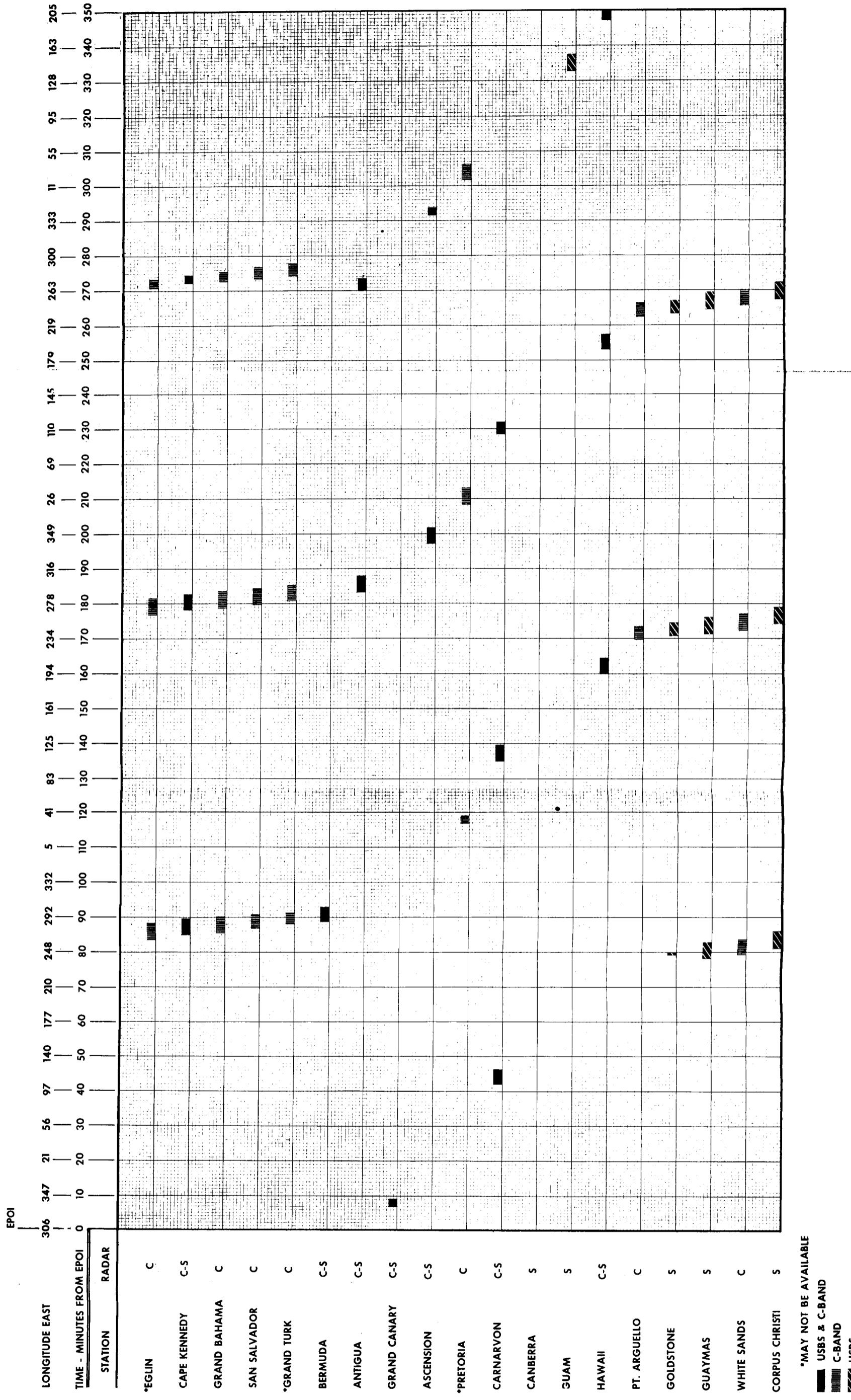
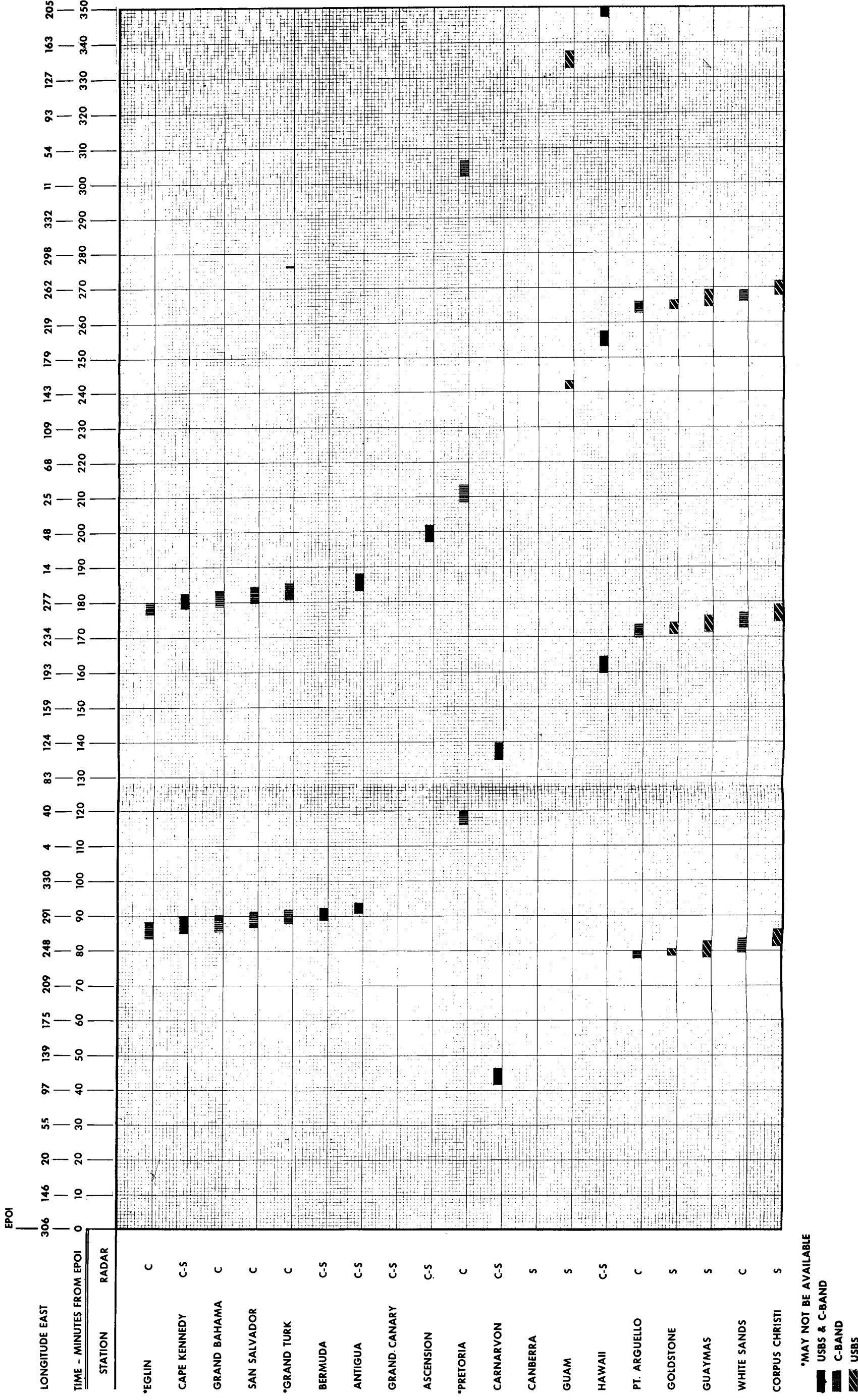
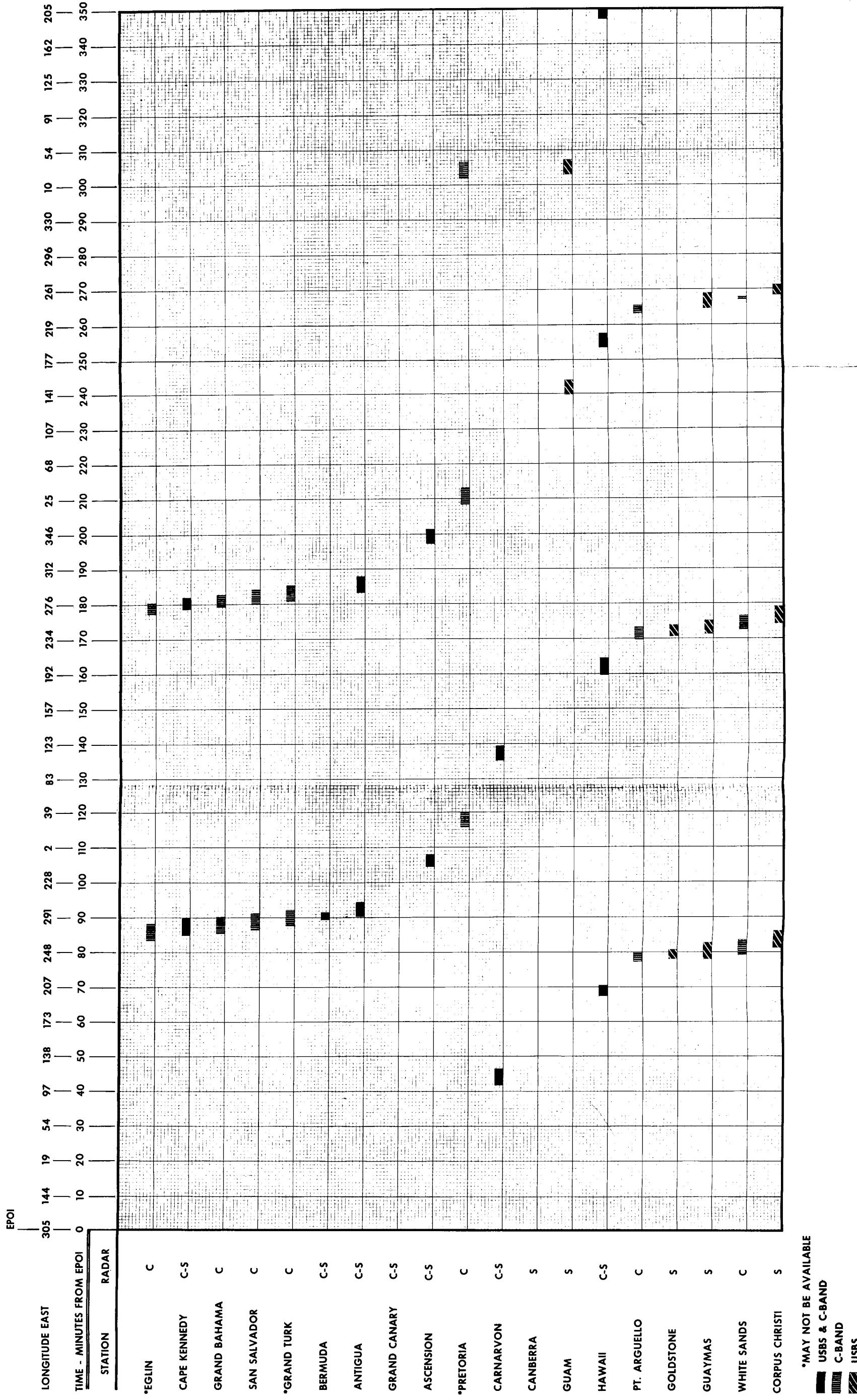


FIGURE 4

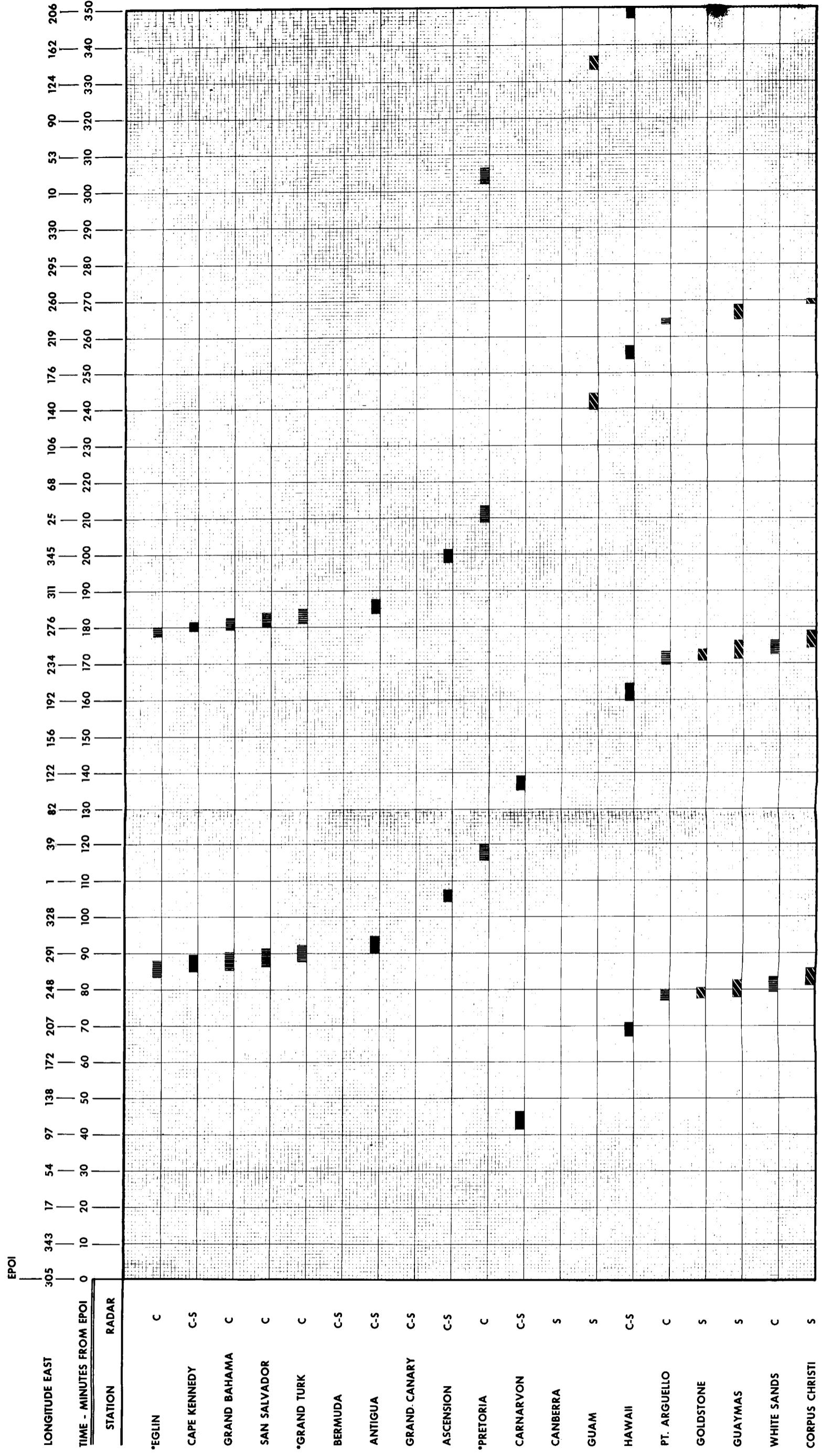
RADAR TRACKING COVERAGE 100 NM ORBIT 84° LAUNCH AZIMUTH  
INITIAL FOUR ORBITS



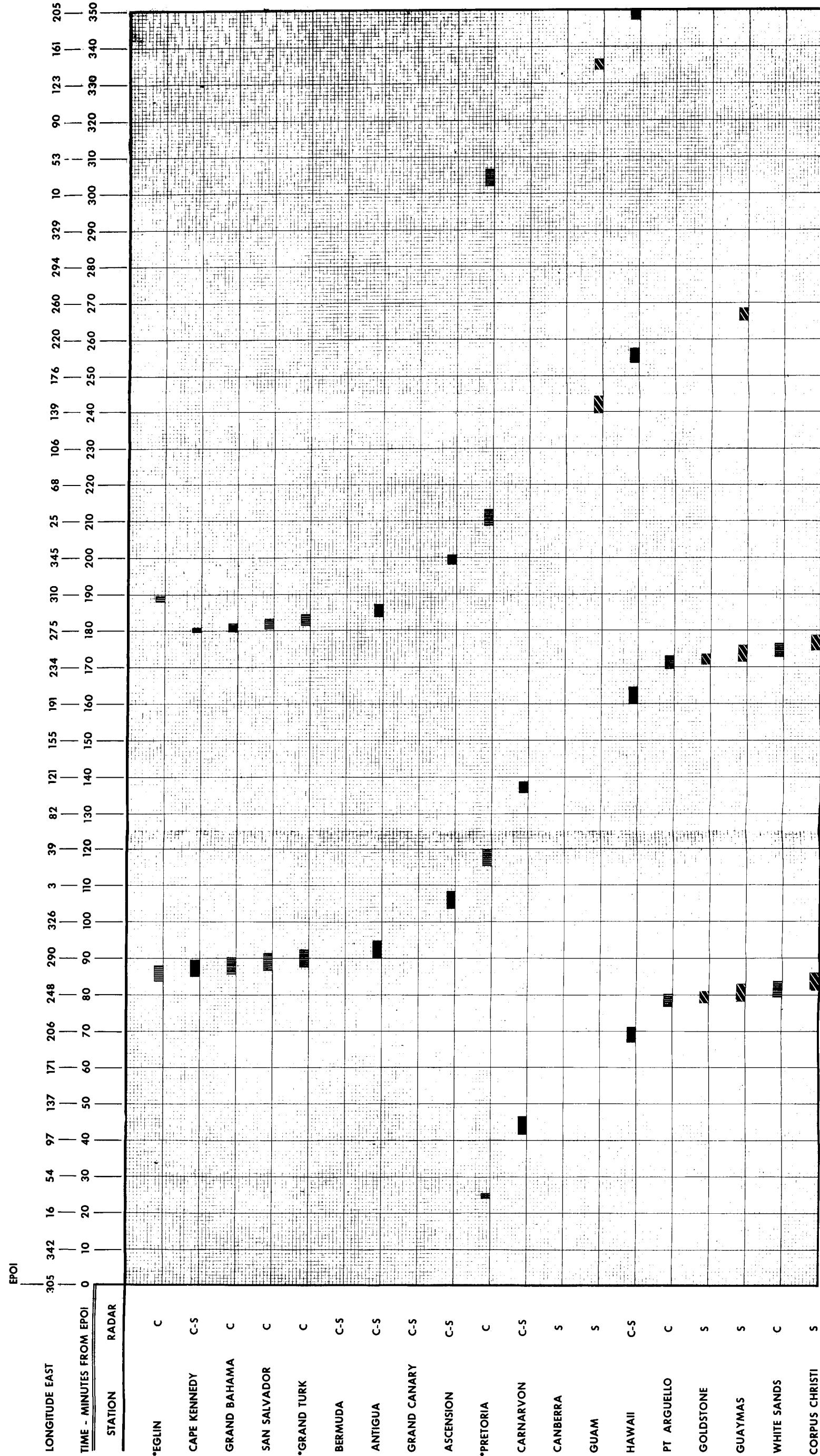
**FIGURE 5**  
**RADAR TRACKING COVERAGE 100 NM ORBIT 88° LAUNCH AZIMUTH**  
**INITIAL FOUR ORBITS**



**FIGURE 6**  
**RADAR TRACKING COVERAGE 100 NM ORBIT 90° LAUNCH AZIMUTH**  
**INITIAL FOUR ORBITS**

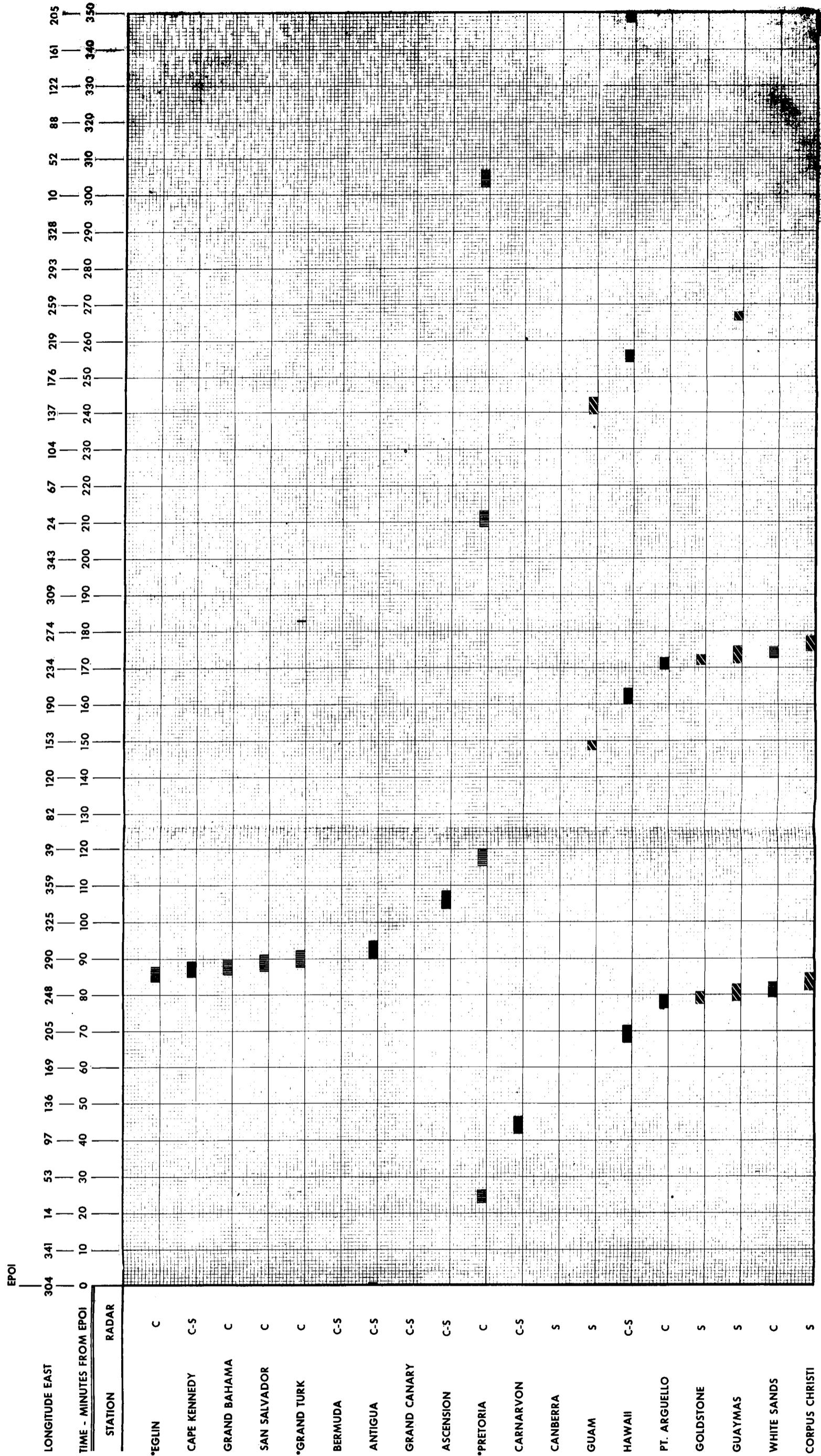


**FIGURE 7**  
**RADAR TRACKING COVERAGE 100 NM ORBIT 92° LAUNCH AZIMUTH**  
**INITIAL FOUR ORBITS**



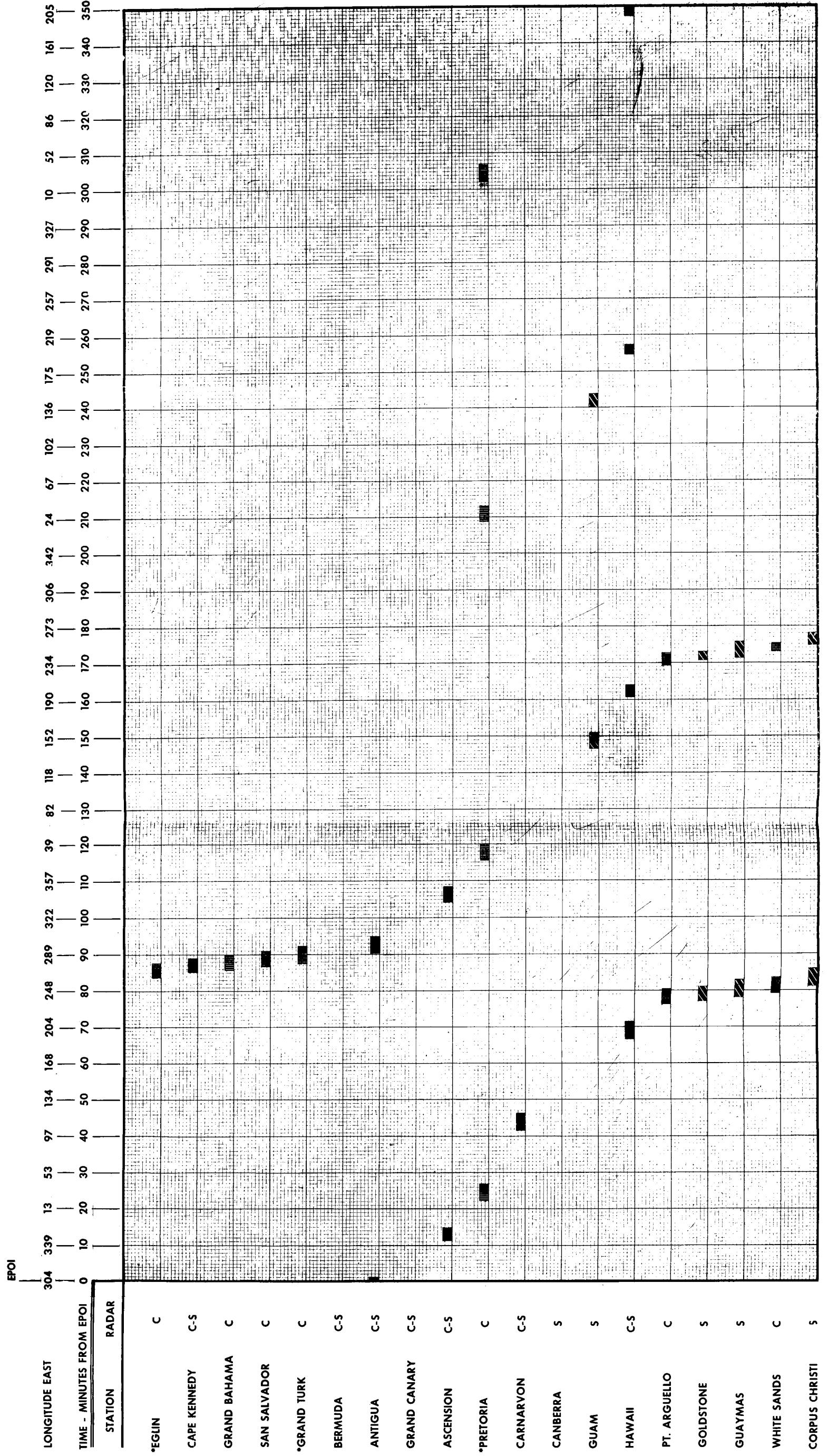
\*MAY NOT BE AVAILABLE  
 USBs & C-BAND  
 C-BAND  
 USBs

**FIGURE 8**  
**RADAR TRACKING COVERAGE 100 NM ORBIT 96° LAUNCH AZIMUTH**  
**INITIAL FOUR ORBITS**

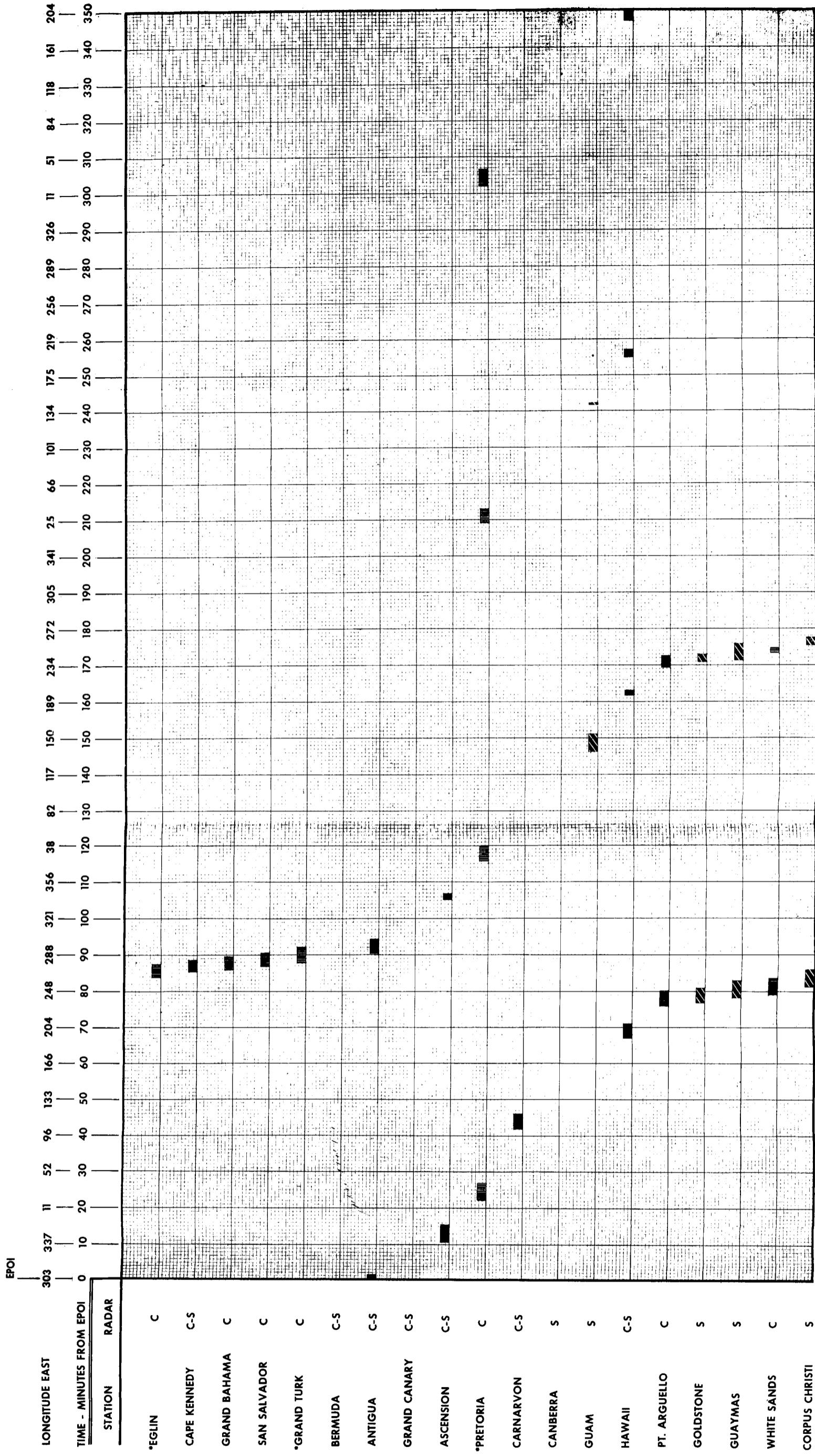


\*MAY NOT BE AVAILABLE  
 USBS & C-BAND  
 C-BAND  
 USBS

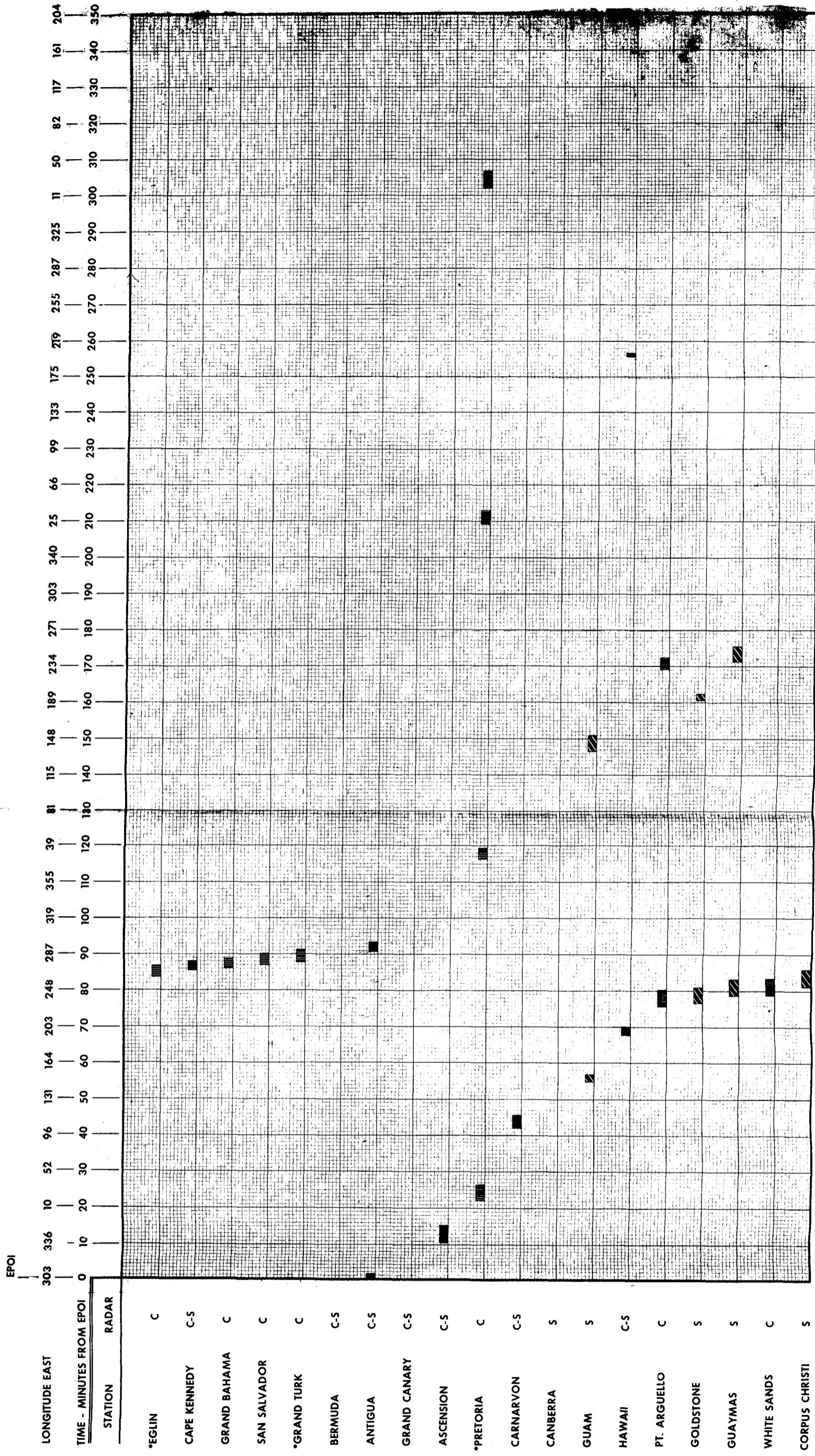
**FIGURE 9**  
**RADAR TRACKING COVERAGE 100 NM ORBIT 100° LAUNCH AZIMUTH**  
**INITIAL FOUR ORBITS**



**FIGURE 10**  
**RADAR TRACKING COVERAGE 100 NM ORBIT 104° LAUNCH AZIMUTH**  
**INITIAL FOUR ORBITS**

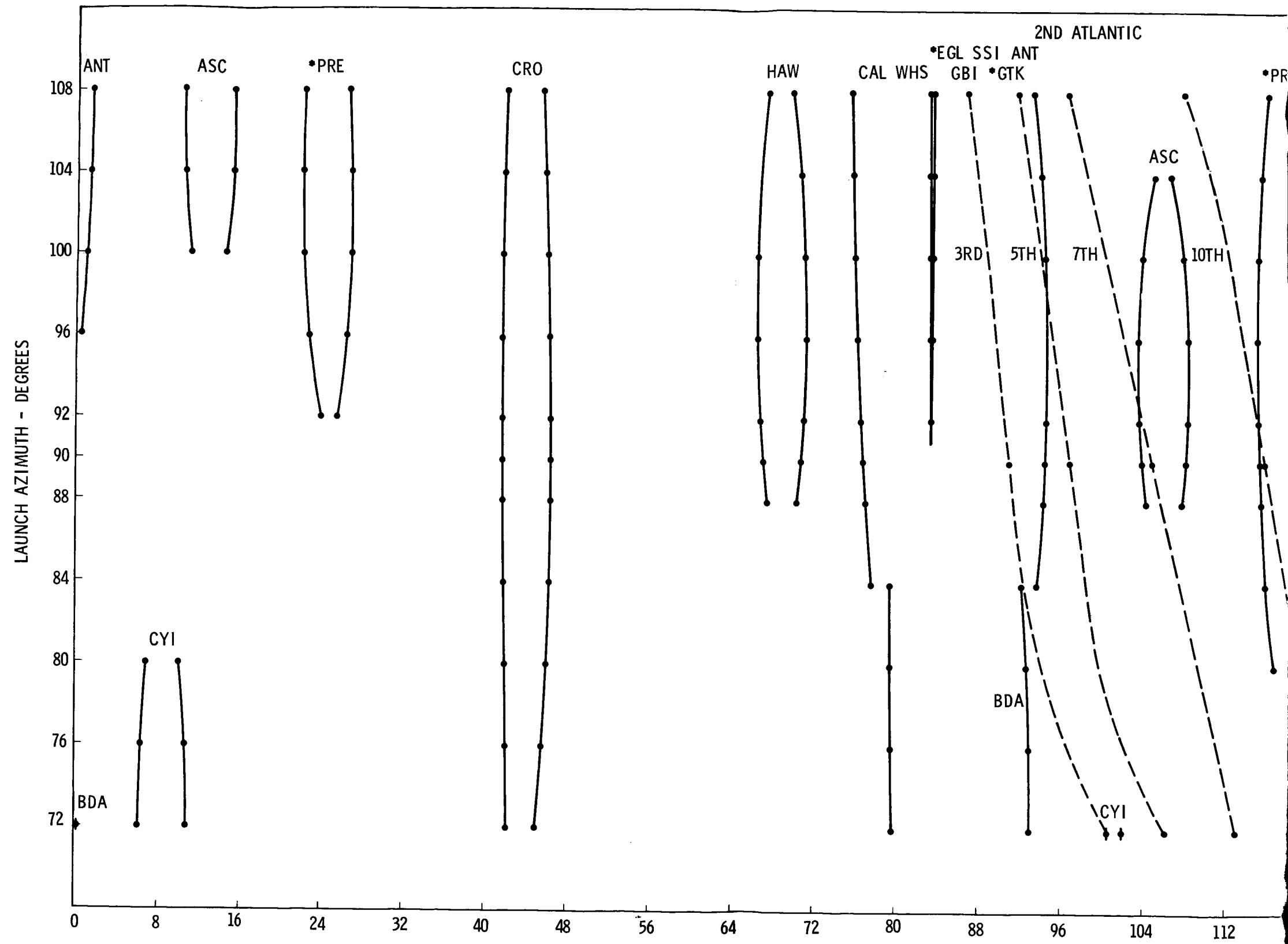


**FIGURE 11**  
**RADAR TRACKING COVERAGE 100 NM ORBIT 108° LAUNCH AZIMUTH**  
**INITIAL FOUR ORBITS**

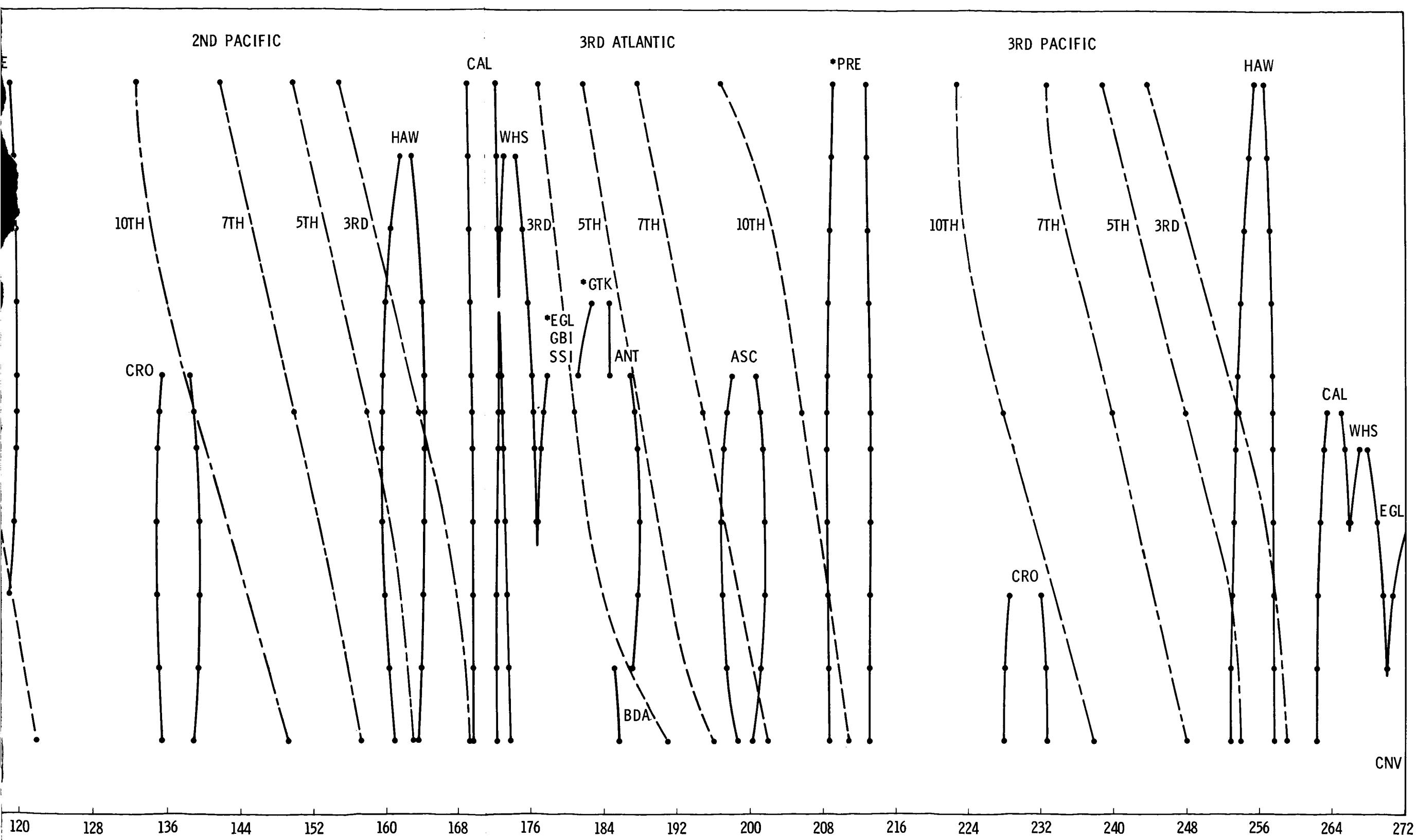


\*MAY NOT BE AVAILABLE

■ USBS & C-BAND  
 ■ C-BAND  
 ■ USBS



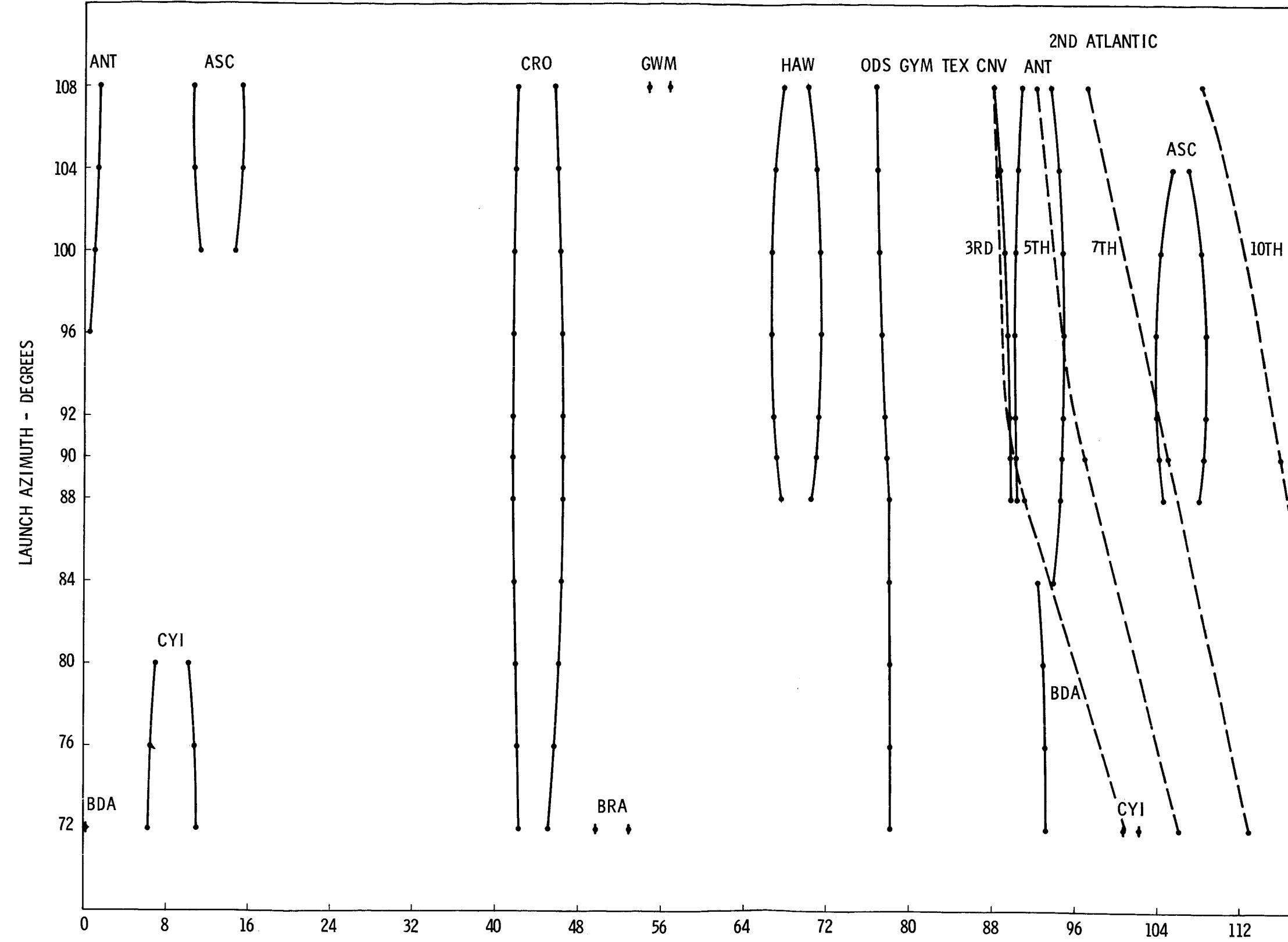
## C-BAND



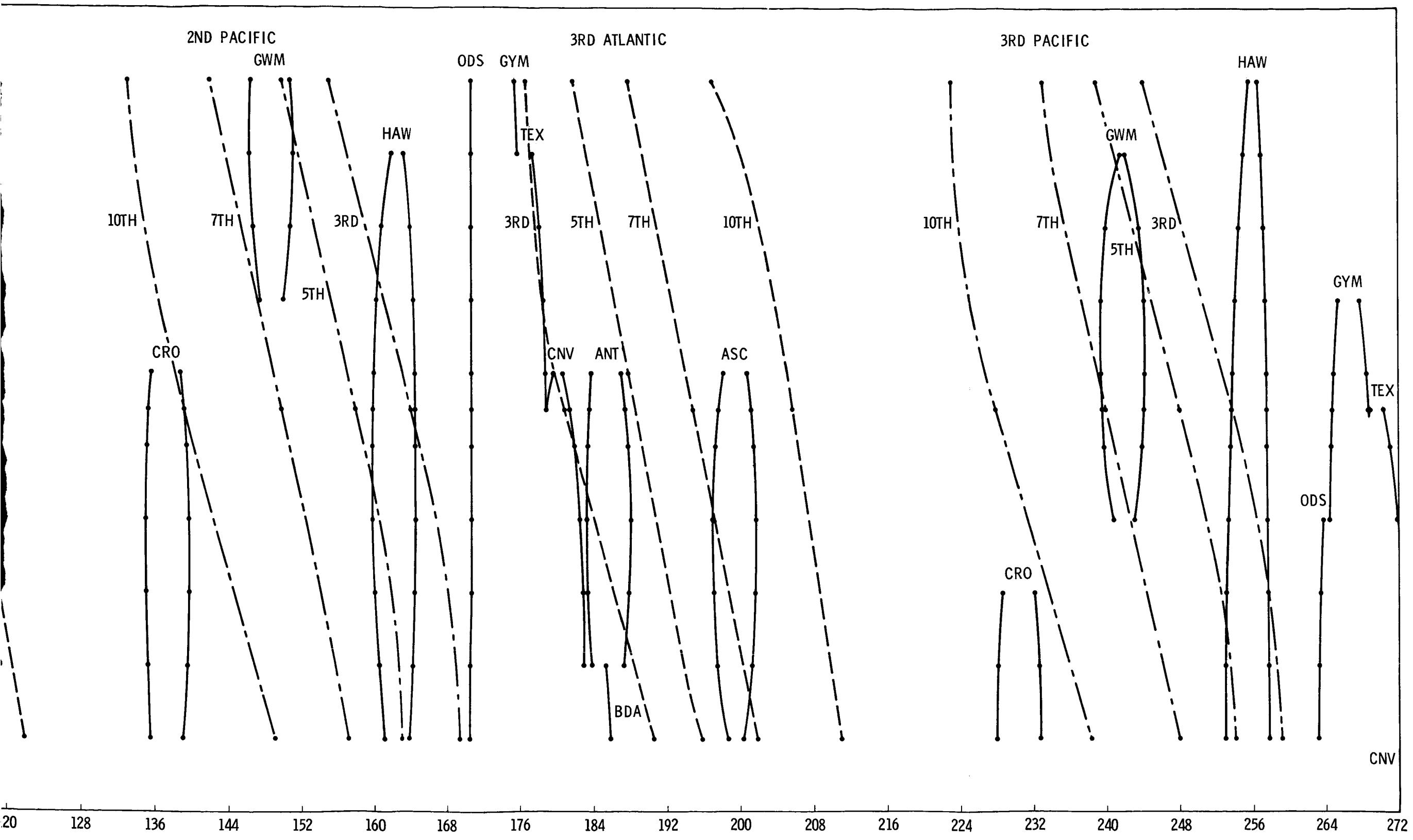
TIME IN MINUTES FROM EPOI

2

FIGURE 12



S-BAND



TIME IN MINUTES FROM EPOI

FIGURE 13

**BELLCOMM, INC.**

SUBJECT: MSFN Navigation Support  
in Earth Parking Orbit  
Case 310

FROM: R. M. Scott

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